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DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH

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NR 098-201

BURNING RATE CONTROL FACTORS
IN SOLID PROPELLANTS

Second Quarterly Status Report

For the Period 1 April 1959 to 30 June 1959

Aeronautical Engineering Report No. 446-b

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I. INTRODUCTION

This report describes progress during the second quarter of a research program directed at studies of mechanisms and control factors of steady state burning of composite solid propellants. The specific aims of the program and its status as of April 1 of this year were outlined in the "Initial Progress Report" dated 27 April 1959.

Included within the program are the following topics: (1) Determination of effects of acoustic stirring upon the burning process, (2) Correlation of burning rate with oxidizer particle size, using precisely sized particles, (3) Comparison of burning rates measured in a strand burner with those measured in a rocket motor, (4) Refinement of the Summerfield granular diffusion flame theory of composite propellant combustion, and (5) Improvement of propellant processing facilities. Progress under topics (1), (2), and (3) is described in this report. Topic (4) awaits further experimental progress and the status of topic (5) remains unchanged pending action by ARPA-ONR on our facilities proposal submitted approximately one year ago (Reference 1).

II. EFFECTS OF ACOUSTIC STIRRING ON BURNING RATE

The motor for investigating effects of acoustic energy has been completed and placed in operation. Seven propellant grains have been processed and fired without mishap. Satisfactory ignition has been obtained by means of a 13-gram jelly-roll igniter. A typical pressure-time record for this motor, with air flowing through the acoustic generator but no sound being generated, is presented in Figure 1.

The air-driven acoustic generator has been tested under non-burning conditions by replacing the motor nozzle with a needle valve. Adjustment of the valve varies the chamber pressure while the generator is operating. The generator output is sensed by a crystal-type pressure pickup and the signal is displayed on an oscilloscope screen. The arrangement of the pickup in the motor is shown schematically in Figure 2. Possible adjustments in the generator configuration are indicated in Figure 3. Changes in the generator supply pressure, the chamber pressure, and/or the generator configuration produce wide variations in the frequency and amplitude of the pressure oscillations measured in the chamber. Many different combinations of these variables lead to strong acoustic oscillations, with observed frequencies ranging from 10 to 100 kcps. and amplitudes as high as 50 psi peak-to-peak. Between these combinations no signal is obtained. It appears that as adjustments are made to the generator the output goes through conditions of resonance with the motor chamber. At these conditions strong oscillations are set up within the system.

Several motor firings have also been made with the ultrasonic generator attached to the head of the motor and with air flowing. The set up of the generator was preselected for each test on the basis of data obtained in the calibration runs described above. To date no effect on chamber pressure or burning rate has been observed in any of these tests. However, our present instrumentation has no provision for measuring high-frequency pressure oscillations during a motor firing. It is therefore not known whether high frequency oscillations are being excited by the whistle under actual firing conditions.

Work in the immediate future on this project will be directed at the following aims:

1. More extensive calibration tests (no live propellant) to provide a more complete understanding of the acoustic generator operation as a function of the several variables which affect the output.

2. Changes in methods of operation or instrumentation to assure that resonant conditions are attained during burning.

III. EFFECTS OF OXIDIZER PARTICLE SIZE ON BURNING RATE

In the program to study the effects of oxidizer particle size on propellant burning rate, effort during the past quarter has been limited to the selection of equipment for measuring particle size distribution. An order has been placed with the Mine Safety Appliances Corporation for a particle size analyser of novel design. The device which they manufacture is a liquid sedimentation - centrifuge type instrument. Particle sizes are measured by the rate of fall through a liquid, and for small particles, this rate is hastened by centrifuging the system. This device was selected on the basis of range of particle size covered, ease of operation and equipment cost. At present, the equipment has not been received. Future work will involve familiarization with the equipment and continuation of the program.

IV. BURNING RATE MEASUREMENT IN ROCKET MOTORS

During this quarter the motor to be used for burning rate measurement has been completed and placed in operation. Satisfactory methods of casting and inhibiting propellant grains have been developed so that burning is limited to specified surfaces. In conjunction with this program, the propellant mixing procedures have been improved so that sufficient propellant can be prepared in one batch for two motor grains. This resulted from modifications to the mixer which allow addition of the oxidizer under vacuum. Better use of mixer capacity is afforded thereby, and it is expected that propellant quality will be improved.

To this date there has been one firing of the burning rate motor; this was successful. A six-gram jelly-roll igniter was used. After firing, the grain inhibitor was left as a shell with only a slight charring evident.

Pressure-time records of test firings will be recorded by a combination of a Bourdon tube pressure transucer, an oscilloscope and a Polaroid Land camera.

The recording equipment is currently being installed.

A theoretical analysis was made of the radiation from the hot gas in the core of an internal burning propellant grain. Calculations show that a total energy feedback to the propellant surface of the order of 70 watts/cm^2 or 230,000 Btu/hr-ft^2 might be expected. This is approximately double the rate of energy measured in the burning of a propellant strand in a cold gas.* It is believed that this may be a clue to the differences observed between burning rates obtained in strand burners and those often obtained in motors.

REFERENCES

1. Princeton University Proposal, Construction of Propellant Processing Facilities to Support Solid Propellant Research, dated 25 July 1958.

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* Project SQUID, Semi-Annual Progress Report, April 1, 1959.

TYPICAL CHAMBER PRESSURE
RECORD WITH AIR FLOW
THROUGH ACOUSTIC GENERATOR

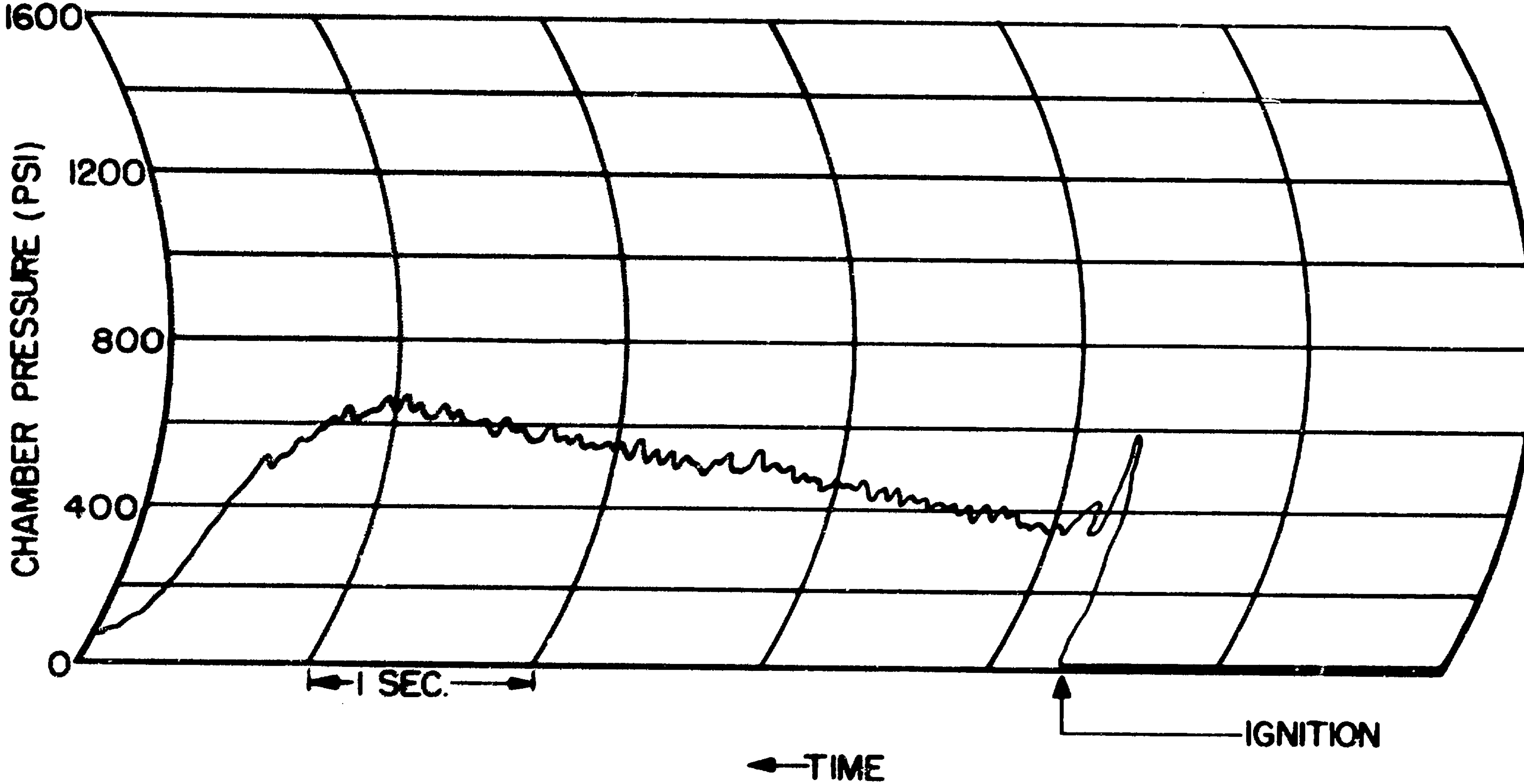

FIGURE 1

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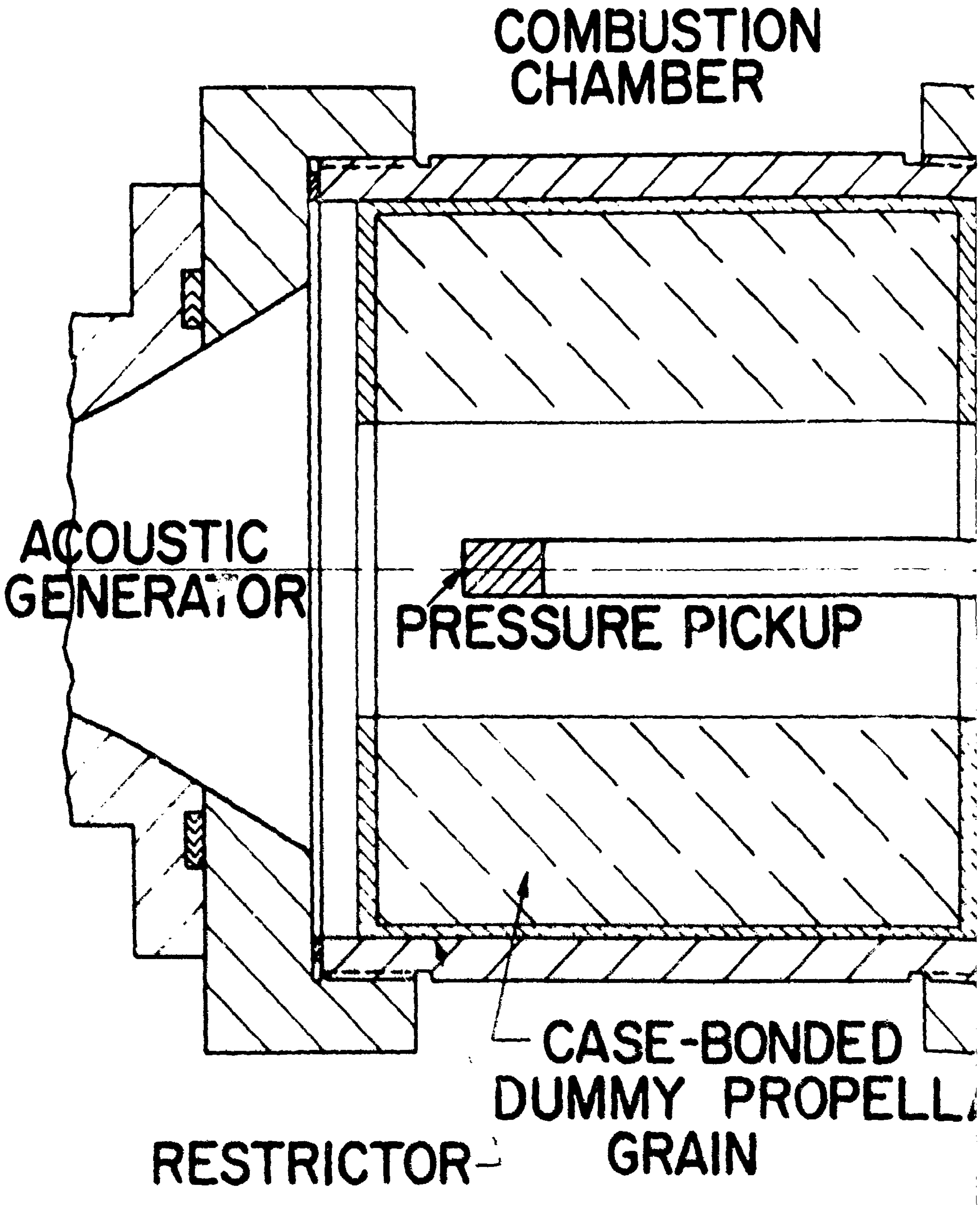
SOLID PROPELLANT M
PICKUP IN PLAC
CHARACTERISTICS OF



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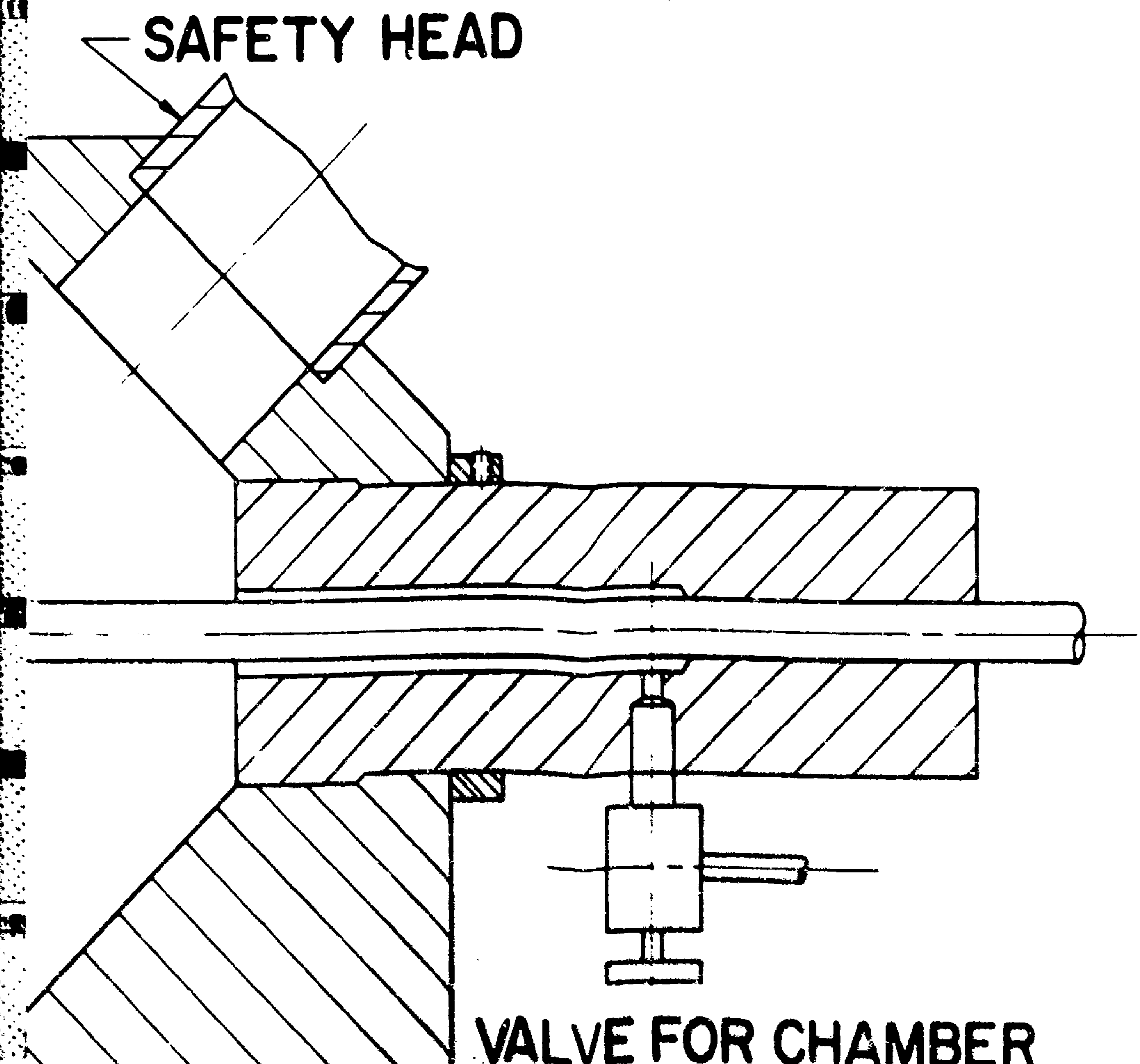
FOR TESTING
ACOUSTIC GENERATOR



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SOLID PROPELLANT MOTOR WITH PRESSURE PICKUP IN PLACE FOR TESTING CHARACTERISTICS OF ACOUSTIC GENERATOR

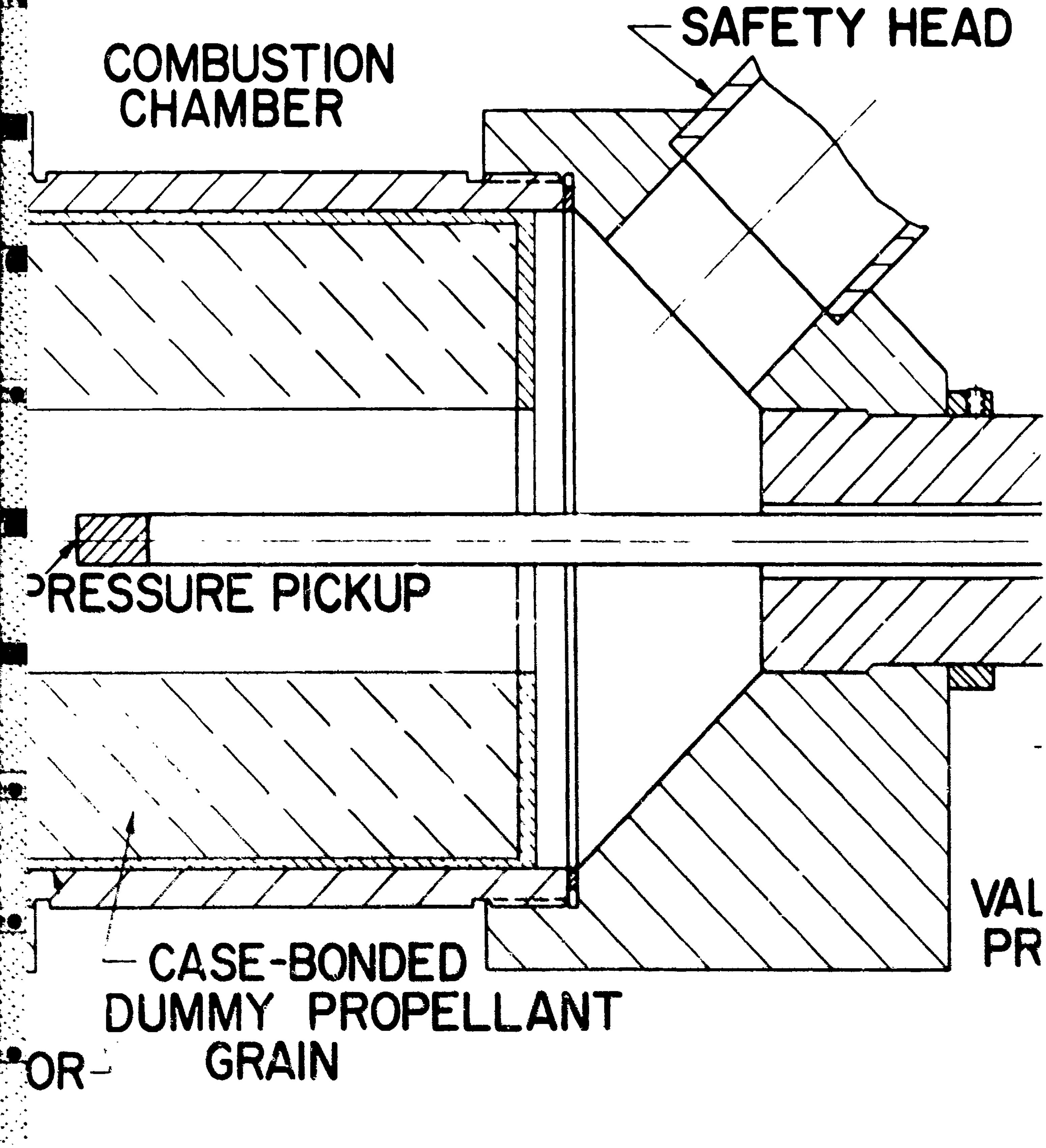
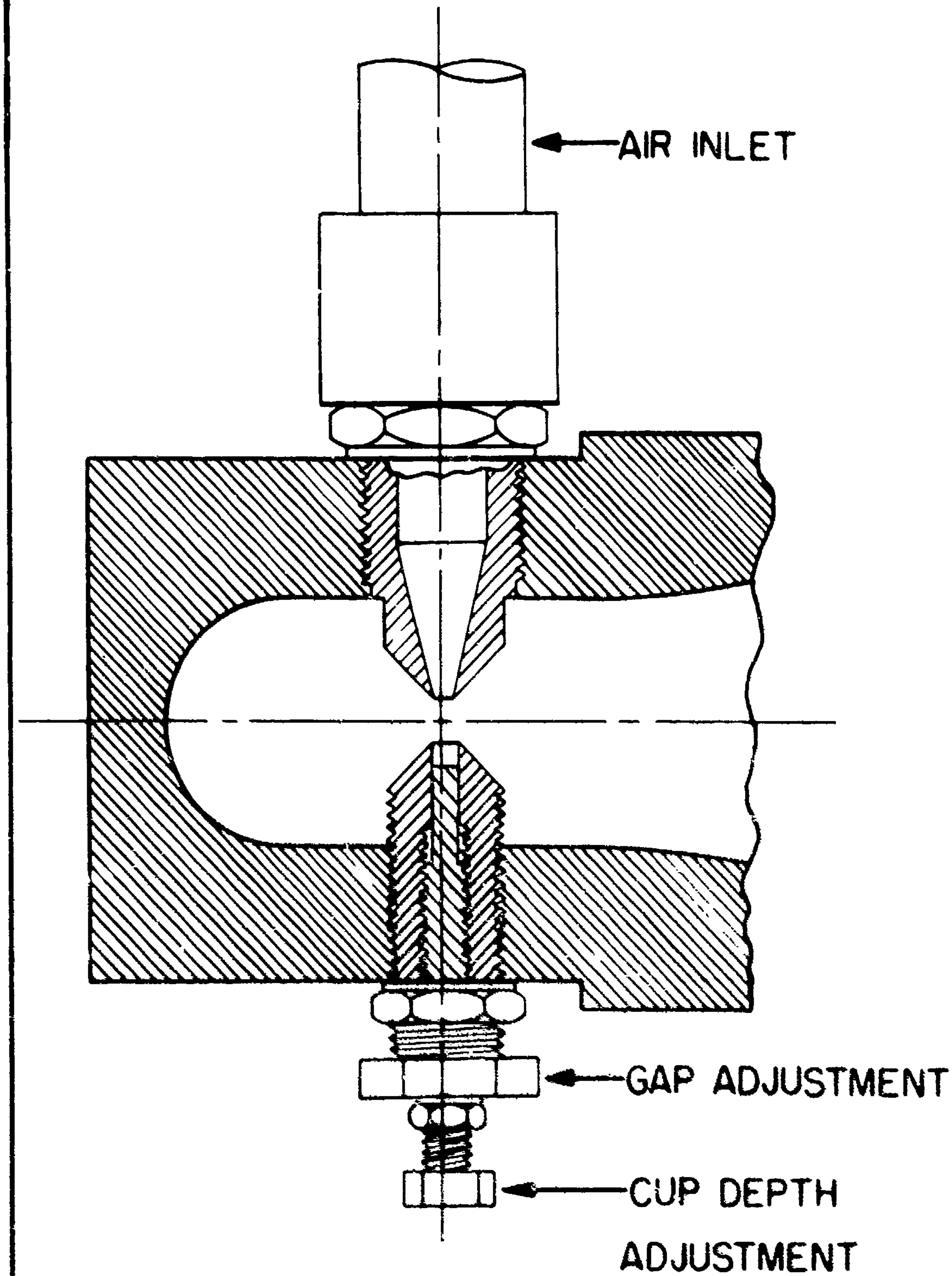


FIGURE 2

ACOUSTIC GENERATOR

FIGURE 3



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